Educational Impact of a Non-Traditional Laboratory for Rock Mechanics Tests

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INTRODUCTION

Engineering education, regardless the area, has solid needs of experimental competence developments (Feisel & Rosa, 2005; Jara, Candelas, Puentes, & Torres, 2011; Gustavsson, et al., 2011). Nowadays, these competences can be worked not only in traditional laboratories (hands-on) but also in non-traditional laboratories (e.g., virtual, and remote laboratories). The use of diversified methods in education and the exploration of new resources and techniques in the classroom may allow teachers to motivate more students and capture their attention due to their different learning styles. (Lima, Viegas & Garcia-Peñalvo, 2017). With the Bologna Process, the time spent in laboratories was reduced in most European Engineering Schools and the number of students per class increased, due to economic restrictions. At the same time scientists started developing computer simulations and remote laboratories, allowing students to practice some experimental skills in a different manner – giving them freedom to organize their own learning activities according to their perception of their learning needs and extended access to the learning resources (access many times and from different places), potentiating students' autonomy (Gustavsson, et al., 2011). To become experts when dealing with complex problems in which high competence level relations must be applied, students must become fluent in the language of nature and a successful designer, and for that engineering students must perform numerous experiments and practice laboratory work (Gustavsson, et al., 2011).

Education Technologies, like virtual or simulated laboratories, certainly do not develop the same type of skills when compared with hands-on based laboratories, or even remote laboratories. While simulations can be used anywhere/anytime, they obey a mathematical model. However, this does not mean their usage is mutually exclusive. In this sense, several authors sustain the idea that these technologies can be used in a complementary approach while identifying the different contributions that can affect the student learning process (Alves, Viegas, Lima, & Gustavsson, 2016; Brinson, 2015), (Corter, Esche, Chassapis, Ma, & Nickerson, 2011).

Non-traditional laboratories (NTL) have become part of current teaching and learning, particularly in engineering. Their potential to aid students beyond their hands-on lab classes has been a matter of discussion in literature. A recent literature review (Al-Atroush, 2020) concluded that the use of NTL has the same or even better effectiveness than Traditional Labs (TL). NTL are effectively used to enhance student's science process skills and can also be used as a medium for distant learning. In addition, NTL also show several advantages such as easy access anytime and anywhere, less costs required and provide flexibility for students to conduct experiments according to their respective ability levels and learning speeds (Usman, et al., 2021). For instance, according to Al-Atroush (2020), over 205 NTL in 9 Engineering & Science disciplines, comprising about 1515 virtual experiments, are currently being accessed by more than 600,000 students. More recently, many "emergency remote teaching" responses to the COVID-19 pandemic were based on an intensive use of NTL (García-Peñalvo et al., 2021; García-Peñalvo, 2022b; Vrgović, Pekić, Mirković, Anderla, & Leković, 2022). Despite that, very few examples on the use of NTL in geotechnical engineering (GE) are reported in current literature. (Al-Atroush, 2020; Schmitz, Nogueira, & Nervis, 2021).

From a scientific perspective, GE largely involves defining the soil's strength and deformation properties. Clay, silt, sand, rock, and snow are important materials in geotechnics. GE is a branch of civil engineering that includes specialist fields such as soil and rock mechanics, geophysics, hydrogeology, and associated disciplines such as geology. In GE, as in other experimental based courses, lab experiments play an essential rule in some specific subjects namely rock and soil mechanics. The need to perform characterization tests of rocks combined with the difficulty in getting test samples for its realization, the short time available for the development of the laboratory practices, absence of enough equipment, large groups of students, etc., potentiates the application of NTL-based teaching and learning methodologies. Nevertheless, developing a rock mechanics non-traditional experimental lab, for instance, may turn out a real challenge due to the complexity of procedures to be followed. In this context, it is vital to increase the offer of NTL in GE and investigate on associated didactical applications able to help students acquiring the right level of experimental competences in this engineering field.

WORK HYPOTHESIS AND MAIN OBJECTIVES TO ACHIEVE

Considering the reduced offer of NTL in GE, particularly in experiments on rock mechanics, this thesis project will investigate on possible ways of creating an NTL, such as visualized experiments or Easy Java Simulations (Esquembre, 2019), and set-up didactical implementations based on the combined use of TL and NTL to evaluate the acquisition of experimental competences in this specific area.

Considering this problematic, the main goal of this work aims to study the following Research Questions (RQ):

- **RQ1: How did Non-Traditional Labs (NTL) evolved in Geotechnical Engineering, particularly during "emergency remote teaching"?**
- **RQ2: Which are the strengths and limitations of these tools applied to geotechnical laboratories, namely in rock mechanics laboratory?**
- **RQ3: How to develop NTL for rock mechanics laboratory practices?**
- **RQ4: What is the educational impact of simultaneously using TL and NTL to support the acquisition of experimental competences in rock mechanics?**

METHODOLOGY

Educational Research consists of applying the scientific method to the educational problems study, with the goal of explaining, predicting and/or controlling educational phenomena (Gay, Mills, & Airasian, 2011) Educational research originates with at least one question about one phenomenon of interest and can be regarded as an organized approach to asking, answering, and effectively reporting a question, with steps parallel to the ones in scientific method. (Williams, C., 2007).

To conduct this research work, a mixed methods approach will be used, that is, it will be incorporated in a unique research study methods of colleting or analysing data from the quantitative and qualitative approaches (Creswell, 2014).

Geotechnical engineering involves the integration of fundamental principles on the physical and mechanical behaviour of soils and rocks and make use of laboratory tests to determine their parameters. Thus, the importance of the laboratory component is all too evident in this area as it is in other lab-based courses.

After a brief review of the published literature, namely regarding the implementation of NTLs in laboratory practices of GE and specifically in the use of these tools for rock characterization tests, was verified that there is a gap in this area. It is worth noting that there are numerous publications on the use of NTLs for soil mechanics laboratory tests.

It seems to be mandatory to carry out a systematic literature review of the use of these tools in rock mechanics laboratory practices (García-Peñalvo, 2022a).

NTLs are a broad category of labs that comprehend virtual, online, remote, or hybrid laboratories (Esposito, et al.,2021) The decision on which NTL to use follows from an important analysis on which kind of tool to undertake and that best suit rock mechanics tests. Conducting a Swot analysis and/or cross-analysis of some of the major differences among NTLs, its strengths and weaknesses, all hands-on rock mechanics experiments, and the learning goal(s) associated with each experiment will allow an informed choice of the type of NTL most suitable for the specificities of rock characterization tests.

The key issue in this research, in addition to selection, is how to develop the NTL. Creating an NTL for characterization tests of rock may be more complicated than in other disciplines owing to the relatively detailed procedures and specifications that should be followed, which may make the development process more sophisticated. This development process can be summarized in 4 main steps:

(1) To survey the tools available, Easy Java Simulations, visualized experiments, for example, and if we can use them in the development of the NTL.
(2) Depending on the NTL tool(s) selected, verify what needs to be done to meet the rock mechanics test or testing specifications and propose a methodology, to verify what needs to be done to meet the specifications of the rock mechanics test or tests and propose a methodology.
(3) Elaborate a validation plan.
(4) Didactical implementation - the samples that will be used are students/teachers from Geotechnical and Geoenvironmental Engineering from Polytechnic Institute of Porto- School of Engineering.

Finally, for data analysis, a qualitative and quantitative cross analysis will be done, considering several items, namely: Participation and/or delivery of proposed tasks (in due time), Access logs (quantity and distribution over time), presences to classes, students final grades, participation and/or delivery of proposed tasks (in due time), students' PLEQ questionnaire, teachers interview and/or informal comments, time used in giving feedback and type of feedback given to each assessment task.

This research will follow the Bera's Ethical Guidelines for Educational Research (BERA, 2018).

MATERIAL MEANS AND RESOURCES AVAILABLE

This work is carried out in the PhD programme: Training in the Knowledge Society (García-Peñalvo, 2013, 2014, 2017, 2021), with its portal being the main tool for communication and visibility of progress (García-Peñalvo et al., 2019b). This thesis is developed in the GRIAL Group of the University of Salamanca (García-Peñalvo et al., 2019a; GRIAL Group, 2019). The results of this thesis will be openly accessible (Ramírez-Montoya et al., 2018).

For the literature review phase, all databases made available by both the University of Salamanca and the Polytechnic of Porto – School of Engineering will be used.

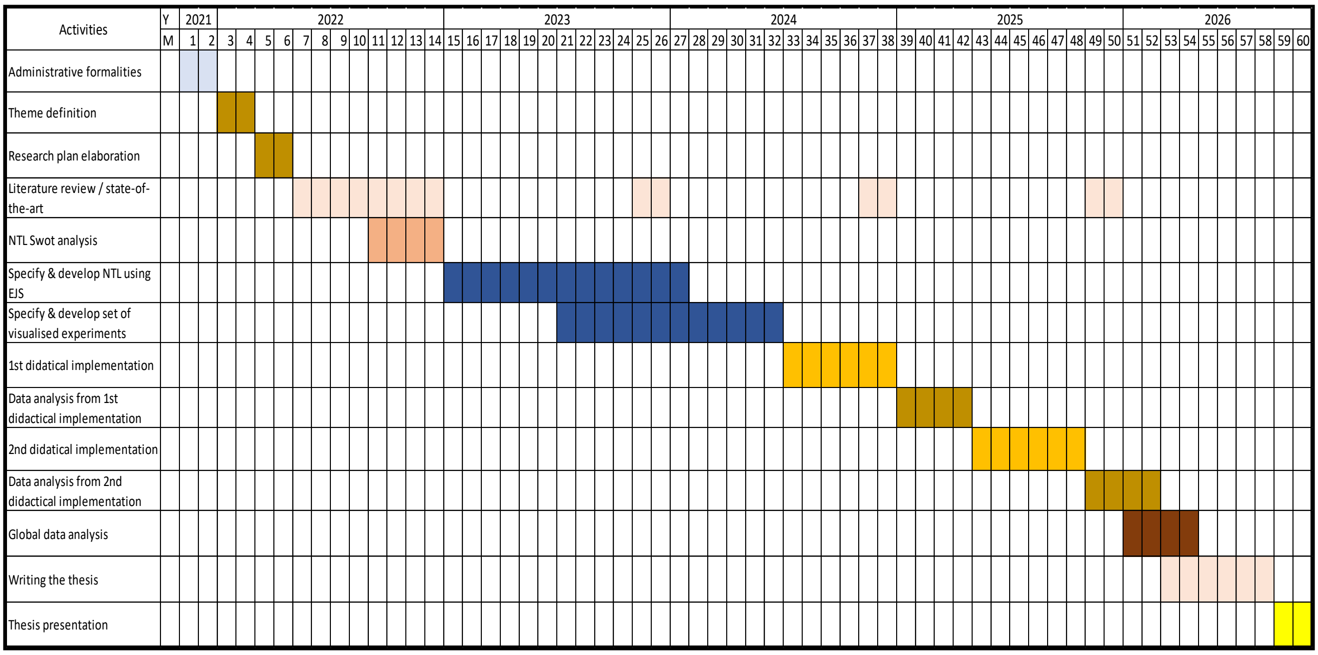
All equipment and resources of Rock Mechanics Laboratory of Geotechnical Engineering Department at the Polytechnic of Porto – School of Engineering are available for the research work.

Most of the required data will be provided through Moodle platform, Interviews and PLEQ questionnaires. For data analysis, we will use the statistical tool SPSS (Statistical Package for Social Sciences).

All resources available at CIETI-LABORIS (Centro de Investigação em Engenharia e Tecnologia Industrial – Núcleo de Investigação em Sistemas de Testes) Research Group, can be used in the different phases of the research.

TIMING SCHEDULE OVER FIVE YEARS (Part time)

This research is expected to be completed in five years as the registration in this PhD Program is part-time. Thus, the activities developed to fulfil the research objectives are scheduled for a period of 5 years, as shown in the table below:



Over this 5-year period, it is intended to disseminate the results obtained in each research phase, namely:

- Participation in activities fostered by the PhD Education in the Knowledge Society Program;
- Participation (with submission and paper presentation) in the future editions of Technological Ecosystems for Enhancing Multiculturality Conferences (TEEM);
- Participation (with submission and paper presentation) to the future editions of Congresso National de Prácticas Pedagógicas no Ensino Superior (CNAPPES);
- Participation in future editions of International Conference on Geo-Engineering Education (GEE);
- Participation in the future editions of other relevant Conferences, such as International Conference of the Portuguese Society for Engineering Education (CISPEE); Remote Engineering and Virtual Instrumentation (REV) Conference, and Experiment@International Conference (EXP@), among others.

REFERENCES

Al-Atroush, M., Ezzat, (2020) In-Person and Virtual Balanced Technique for Geotechnical Engineering Laboratories, ICERI2020 Proc., vol. 1, no. December, pp. 7901–7910.

Alves, G., Viegas, C., Lima, N., & Gustavsson, I. (2016). Simultaneous Usage of Methods for the Development of Experimental Competences. International Journal of Human Capital and Information Technology Professionals 7(1), 48-63

British Educational Research Association (BERA). (2018). Ethical Guidelines for Educational Research (4th ed.). British Educational Research Association (BERA). https://bit.ly/35ZT8v1

Brinson, J. R. (2015). Learning outcome achievement in non-traditional (virtual and remote) versus traditional (hands-on) laboratories: A review of the empirical research. Computers and Education, 87, 218–237.

British Educational Research Association (BERA). (2018). Ethical Guidelines for Educational Research (4th ed.). British Educational Research Association (BERA).https://bit.ly/35ZT8v1

Corter, J. E., Nickerson, J. V., Esche, S., Chassapis, C., Im, S., & Ma, J. (2007). Constructing reality: A study of remote, hand-on and simulated laboratories. ACM Transactions on Computer Human Interaction, 14(2).

Creswell, J. W. (2014). Research Design: Qualitative, Quantitative and Mixed Methods Approaches, 4th Edition. SAGE.

Esposito, G., Mezzogori, D., Reverberi, D., Romagnoli, G., Ustenko, M., Zammori, F. (2021). Non-Traditional Labs and Lab Network Initiatives: A Review. International Journal of Online and Biomedical Engineering (iJOE), 17(05), pp. 4–32. https://doi.org/10.3991/ijoe.v17i05.20991

Esquembre, F. (2019) Easy Java Simulations Modeling and Authoring Tool. Available on https://www.compadre.org/osp/items/detail.cfm?ID=7305. Accessed April 18, 2022.

Feisel, L.D., Rosa, A.J., (2005) The Role of the Laboratory in Undergraduate Engineering Education, Journal of Engineering Education, Jan. 2005, pp 121-130.

García-Peñalvo, F. J. (2013). Aportaciones de la Ingeniería en una Perspectiva Multicultural de la Sociedad del Conocimiento. VAEP-RITA, 1(4), 201-202.

García-Peñalvo, F. J. (2014). Formación en la sociedad del conocimiento, un programa de doctorado con una perspectiva interdisciplinar. Education in the Knowledge Society, 15(1), 4-9. https://doi.org/10.14201/eks.11641

García-Peñalvo, F. J. (2017). *Education in the Knowledge Society PhD Programme. 2017 Kick-off Meeting* Seminarios del Programa de Doctorado en Formación en la Sociedad del Conocimiento (16 de noviembre de 2017), Salamanca, España. https://goo.gl/bJ5qKd

García-Peñalvo, F. J. (2022a). Developing robust state-of-the-art reports: Systematic Literature Reviews. Education in the Knowledge Society, *23*, Article e28600. https://doi.org/10.14201/ eks.28600

García-Peñalvo, F. J. (2022b). El sistema universitario ante la COVID-19: Retrospectiva y prospectiva de la transformación digital. In F. Llorens Largo & R. López-Meseguer (Eds.), Transformación digital de las Universidades. Hacia un futuro postpandemia (pp. 142-148). Universidad Internacional de La Rioja (UNIR).

García-Peñalvo, F. J. (2021). Sesión de inicio (kick-off meeting) del Programa de Doctorado Formación en la Sociedad del Conocimiento: Curso 2021-2022 Seminarios del Programa de Doctorado en Formación en la Sociedad del Conocimiento (2 de noviembre de 2021), Salamanca, España. https://bit.ly/3CDtMlr

García-Peñalvo, F. J., Corell, A., Abella-García, V., & Grande-de-Prado, M. (2021). Recommendations for Mandatory Online Assessment in Higher Education During the COVID-19 Pandemic. In D. Burgos, A. Tlili, & A. Tabacco (Eds.), Radical Solutions for Education in a Crisis Context. COVID-19 as an Opportunity for Global Learning (pp. 85-98). Springer Nature https://doi.org/10.1007/978-981-15-7869-4_6

García-Peñalvo, F. J., Rodríguez-Conde, M. J., Therón, R., García-Holgado, A., Martínez-Abad, F., & Benito-

Santos, A. (2019a). Grupo GRIAL. IE Comunicaciones. Revista Iberoamericana de Informática Educativa(30), 33-48. https://bit.ly/35IIQh9

García-Peñalvo, F. J., Rodríguez-Conde, M. J., Verdugo-Castro, S., & García-Holgado, A. (2019b). Portal del Programa de Doctorado Formación en la Sociedad del Conocimiento. Reconocida con el I Premio de Buena Práctica en Calidad en la modalidad de Gestión. In A. Durán Ayago, N. Franco Pardo, & C. Frade Martínez (Eds.), Buenas Prácticas en Calidad de la Universidad de Salamanca: Recopilación de las I Jornadas. REPOSITORIO DE BUENAS PRÁCTICAS (Recibidas desde marzo a septiembre de 2019) (pp. 39-40). Ediciones Universidad de Salamanca https://doi.org/10.14201/0AQ02843940

Gay, L., Mills, G. E., & Airasian, P. W. (2011). Educational Research: Competencies for Analysis and Applications, 10th Edition. Pearson. Automatics and Robotics. Computer and Education, 57, 2451-2461.

Grupo GRIAL. (2019). Producción Científica del Grupo GRIAL de 2011 a 2019 (GRIAL-TR-2019-010). https://bit.ly/30l9mLh

Gustavsson, I., Alves, G., R., C., Nilsson, K., Zackrisson, J., Hernandez-Jayo, U., & Garcia_Zubia, J. (2011). The VISIR Open Lab Platfrom 5.0 - an architecture for a federation of remote laboratories. REV 2011: 8th International Conference on Remote Engineering and Virtual Instrumentation. Brasov, Romania

Lima, N., Viegas, C., García-Peñalvo, F. (2017). Learning from complementary ways of developing experimental competences, Journal Education in the Knowledge Society (EKS), *18*(1), 63-74.

Jara, C., Candelas, F., Puentes, S., & Torres, F. (2011). Hands-on experiences of undergraduate students in Automatics and Robotics. Computer and Education, 57, 2451-2461.

Ramírez-Montoya, M. S., García-Peñalvo, F. J., & McGreal, R. (2018). Shared Science and Knowledge. Open Access, Technology and Education. Comunicar, *26*(54), 1-5.

Schmitz, A.; Nogueira, M. L.; Nervis, L. O. (2021) Interfaces em Laboratório Virtual de Aprendizagem em Engenharias – Caracterização Física de Solos. Revista de Ensino de Engenharia, 40, p.497-509, https://doi.org/10.37702/REE2236-0158.v40p497-509.2021

Usman, M, Suyanta, Huda, K (2021) Virtual lab as distance learning media to enhance student's science process skill during the COVID-19 pandemic, J. Phys. Conf. Ser., vol. 1882, no. 1, p. 012126.

Vrgović, P.; Pekić, J.; Mirković, M.; Anderla, A.; Leković, B. (2022) Prolonged Emergency Remote Teaching: Sustainable E-Learning or Human Capital Stuck in Online Limbo? Sustainability, *14*, 4584. https://doi.org/10.3390/su14084584

Williams, C. (2007). Research Methods. Journal of Business & Economic Research, Volume 5, Number 3